# Dichotic Word Recognition of Young Adults in Adverse Listening Conditions

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by

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## ABSTRACT

The purpose of the present study was to measure dichotic word recognition performance in both noise and with simulated hearing loss in young adults with normal hearing to better compare performance to that of older adults with sensorineural hearing loss. Ten right-handed young adults with normal hearing participated. Dichotic word recognition was measured in three conditions: (1) in quiet, (2) in a background of speech spectrum noise, and (3) with simulated hearing loss (Moore & Glasberg, 1993). A free-recall response paradigm was used for each condition in which listeners were required to repeat both dichotic stimuli regardless of order. As expected, results revealed significant decreases in overall recognition performance in the noise and simulated hearing loss conditions relative to the quiet condition. Despite the decreases in overall recognition performance, the right ear advantages (differences between ear performance) were not significantly different across listening conditions (i.e., they remained relatively small). The young adult REA data was also compared to the older adult data from Roup et al. (2006). Results revealed that the older adults exhibited a significantly larger REA compared to the young adults, despite similar levels of overall recognition performance. These results support the proposed hypothesis that the large REAs exhibited by older adults reflect declines in auditory processing rather than their hearing loss. Declines in auditory processing among older adults have been associated with difficulty with the use of bilateral hearing aids. If the REA is due to declines in auditory processing, it may be more beneficial to fit those patients with one hearing aid rather than two.

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## Chapter 1

## INTRODUCTION AND LITERATURE REVIEW

The dichotic listening procedure consists of the presentation of two competing speech stimuli, one in the right ear and one in the left ear, to a subject via headphones. The simultaneous presentation of two different speech signals creates competition between the processing of each stimulus. To examine how the signals are processed, the subject is asked to recall the stimulus from the right ear, the left ear, or both ears. Previous research has shown that subjects were more successful in recalling the stimuli from the right ear rather than from the left, and this phenomenon has been termed the right ear advantage, or REA (Kimura, 1967).

Research has determined the right ear advantage is a function of how the auditory pathways connect to the brain and the occurrence of interhemispheric transfer. The signals entering the ears travel to the brain through both contralateral auditory pathways, where they cross over to the other side of the brain, and ipslateral pathways, where they travel up the same side to the brain. Research has shown that the contralateral pathways are stronger than the ipslateral pathways, and during dichotic listening procedures, the ipslateral pathways are suppressed, and all stimuli travel contralaterally to the brain. Stimuli presented to the right ear travel directly to the left hemisphere where language is typically processed. The left ear sends auditory stimuli to the right hemisphere, where it then must cross over via the corpus callosum to the left hemisphere for processing (Kimura 1967). During this interhemispheric transfer, energy can be lost creating a disadvantage for the left ear (Jerger, Alford, Lew, Rivera & Chmiel 1995). These conditions result in the right ear advantage observed in many of the test subjects during dichotic listening tasks.

## The Right Ear Advantage and Age Effects

Since the right ear advantage has been observed, researchers have investigated varying degrees of REAs and determined that larger advantages are seen in older adults with sensorineural hearing loss who also exhibit poorer overall recognition performance in dichotic word recognition tasks (Bellis & Wilber 2001). Young adults exhibit much smaller REAs in comparison. The poorer performance of the older adults is related to the fact that the older adults are more likely to display an age-related hearing loss. The larger REAs observed in the older adult population can be due to either the hearing loss, or a deficit in the interhemispheric transfer as many researchers are currently suggesting. The older adults may experience an additional loss of energy during the interhemispheric transfer that occurs from the aging of the central auditory pathways (Jerger, Alford, Lew, Rivera &Chmiel 1995).

In 2001, Bellis and Wilber conducted a research study to examine the REA found in different age groups during dichotic listening tasks. The 120 right-handed test subjects were divided into four groups based on age; age 20-25, age 35-40, age 55-60, and age 70-75. The researchers used dichotic listening tasks, auditory temporal patterning, and interhemispheric time tasks to assess interhemispheric integrity. The results showed that REAs were found in all age groups, but the older participants showed much larger REAs than the younger groups. Larger decreases in performance were first observed between the 40-55 year old age groups, and the significantly larger REAs were seen in the 70-75 age group, suggesting poorer central auditory processing as the reason for the large REA.

When an auditory signal enters the left ear and travels contralaterally to the right hemisphere, the signal then must cross the corpus callosum to the left hemisphere where it can be processed. Aging may affect the ease of this communication between the two hemispheres of the brain. With decreased performance of the corpus callosum, the transfer of a speech signal from the right hemisphere to left is impeded, resulting in less understanding of speech entering the left ear (Jerger, Alford, Lew, Rivera & Chmiel, 1995). This disadvantage of the left ear does not typically occur for the right ear since the right ear signal travels directly to the language-processing center.

## Stimuli

Different stimuli can be used to measure dichotic word recognition performance including digits, words, sentences, and consonant-vowels. Digits are most commonly used because they limit contextual cues. However, digits are a closed-set task and highly familiar, which limits the number of possible responses increasing the likelihood of the test subject correctly guessing the presented digit (Strouse & Wilson, 1999). Another stimulus option, rather than using digits, is monosyllabic words. From use of monosyllabic words, syntactical cues are limited, standardized words lists are easily available and frequently used, a large normative database for listeners with normal and impaired hearing exists for all age groups, and monosyllabic words are an open-set stimulus making them neither too easy nor too difficult when used (Roup, Wiley & Wilson, 2006). The other two stimulus options, sentences and consonant-vowel pairs, are less advantageous and not as frequently used. When listening to sentences there are many contextual cues available to the participant for them to be useful in dichotic listening tasks, and many researchers believe the consonant-vowel stimuli are too difficult. When selecting stimuli to use for the evaluation of the right ear advantage during dichotic listening procedures, it is important to factor in the difficulty of the task. This is because the size of the REA is dependent upon the difficulty of the task (Wilson & Jaffe, 1996). A larger REA will be observed when using a more difficult task; the smallest REAs are exhibited when using digits and the largest REAs are exhibited when using consonant-vowels. Monosyllabic words and sentences result in REAs that fall between the REAs from digits and consonant-vowels.

## Response Condition

During dichotic word recognition testing, the two most common types of response conditions used are free recall and directed-attention recall. The free recall condition instructs listeners to recall the stimuli from both ears in any order. This response condition typically results in a right ear advantage for both younger and older adults. With the directed-attention recall condition, the listener is instructed to pay attention to the stimuli in the specific ear told to them prior to the presentation of stimuli to both ears. The listener attends to the stimulus in the cued ear while ignoring the stimulus in the non-cued ear. When the right ear is cued, the listener exhibits a large REA, and the REA from directed-attention recall is larger than the REA from free recall. This is because the listener knows ahead of time to ignore the left ear stimulus and put their full attention to hearing the stimulus in the right ear. When the listener is cued to attend to the left ear, a left ear advantage is seen but to a much smaller extent than the advantage observed in the right ear (Strouse, Wilson, & Brush, 2000).

There is a second type of directed-attention recall response in which the listener is instructed to recall the stimulus first from the cued ear then from the non-cued ear. The listener is designated an ear to attend to prior to the presentation of the dichotic stimuli. After the presentation of the stimuli, the listener is asked to repeat the stimulus from the cued ear, and then the listener is asked to repeat the stimulus from the non-cued ear. This response condition is more difficult and results in an exaggerated or much larger REA due to the increased difficulty (Roup, Wiley, & Wilson, 2006).

## Handedness and the Ear Advantage

The majority of both right handed and left handed people process language in the left hemisphere and demonstrate a right ear advantage; however, handedness does impact performance during dichotic testing. The REA seen in left-handed subjects is much smaller than the REA of right-handed subjects. Also the percentage of right-handed subjects that exhibit a REA is much larger than the percentage of left-handed subjects that exhibit a REA, and there is a larger percentage of left-handed subjects with a left ear advantage (Wilson & Leigh, 1996). The statistics from a study that determines the hemisphere of language lateralization through use of sodium amytal injections showed that 90% of right-handed people processed language in the left hemisphere, while only 60% of left-handed subjects processed language in the left hemisphere (Branch, Milner, & Rasmussen, 1964). This results in greater performance variability in left-handed subjects than in right-handed subjects, and this is why handedness is controlled as a variable during dichotic testing.

A more recent study was completed by Wilson and Leigh (1996) in order to further examine dichotic recognition performance of right and left-handed listeners. It was found that out of 24 right-handed subjects and 24 left-handed subjects, the majority of listeners from both groups exhibited a REA. However, the magnitudes of the REAs were much larger in the right-handed subjects than for the left-handed subjects. The results for the right-handed listeners, on average, indicated that 72.8% of the stimuli presented to the right ear were correctly identified, and 56.5% of the stimuli presented to the left ear were correctly identified. This means the average REA for right-handed listeners was 16.3%. The results for the left-handed listeners, on average, indicated that 62.9% of the stimuli presented to the right ear were correctly identified, and 61.1% of the stimuli presented to the left ear were correctly identified. This means the average REA for the left-handed listeners was only 1.8%. The results of this study showed that left-handed listeners have much more variability in performances than right-handed listeners, and this gives further support for controlling handedness during dichotic testing, limiting it to right-handed listeners only.

Gender and the Ear Advantage

Research has shown that gender can affect dichotic listening performances depending on the subject's age. A study completed by Jerger, Chmiel, Allen, and Wilson (1994) compared male and female dicothic listening performance data. The study included data from 356 individuals, 203 males and 153 females, ranging in age from 9-91 years old. The researchers administered a Dichotic Sentence Identification test and used both free recall and directed attention recall response conditions. The results showed the males exhibited much larger REAs than the females. As age increased in the female group, both right and left ear performances were significantly decreased. As age increased in the male group, fewer performance deficits were seen in the right ear, while the left ear performances became worse. Because of these differences, males exhibited significantly larger REAs than the females in the upper age range.

Another study that examined the influence of gender on hemispheric specialization was completed by Piazza (1980). This study included 8 males, 4 right-handed and 4 left-handed, and 8 females, also 4 right-handed and 4 left-handed. Subjects participated in both verbal and nonverbal dichotic listening procedures. The results showed that, in general, males exhibited a stronger left-hemisphere advantage than that observed in the females during speech processing. It was also found that right-handed females have stronger right-hemisphere advantages than males for the processing of non-speech auditory stimuli. Piazza's research gave support to the idea that gender affects the lateralization of information to the hemispheres.

Research has shown that gender can be an important variable to consider during dichotic listening tasks. However, the Bellis and Wilber (2001) study that examined the interactions between aging and gender on interhemispheric transfer had a differing conclusion. They determined that gender effects are only significant when studying a middle-aged population, and are clinically insignificant for the early and late adulthood populations.

## Moller (2007) and Manjot's (2008) Studies

Two previous studies were completed to help determine the cause of the greater right ear advantages seen in the older adult population. In 2007, Moller investigated the effect of introducing noise to the dichotic word recognition (DWR) task on young adults with normal hearing. Speech spectrum noise was used to reduce the DWR performance of the young adults to make the data more comparable to that of the older adults with an age-related hearing loss. Moller tested 10 right-handed individuals, 5 male and 5 female, ages 20-25 using DWR testing and a free recall response condition. She presented 50 dichotic word pairs in the quiet condition and 50 dichotic word pairs at a +11 dB SN ratio (determined through her pilot data).

Moller found that the young adults listening performance in the noise condition was worse than in the quiet condition; however, the reduction in DWR performance did not create much change in the young adults REAs. Moller then compared her data from the young adults to the results of older listeners obtained by Roup et al. (2006). She found that the REAs of the young adults in both the quiet and noise conditions remained significantly smaller than the REAs of the older adults. Moller's findings support the current hypothesis that the large REAs observed in older adult population is due to a central auditory processing deficient rather than just and age-related or sensorineural hearing loss.

In 2008, Monjot completed a similar study but instead of using the speech spectrum noise as the form of hearing loss simulation, she used part of the Moore and Glasberg hearing loss simulation model. This method of simulated hearing loss better resembled the hearing loss found in the older adults with sensorineural hearing loss. The speech spectrum noise in the DWR testing does not simulate all aspects of an age-related hearing loss. Age-related sensorineural hearing loss affects the higher frequencies more noticeably than the lower frequencies, however, the use of speech spectrum noise is not frequency specific. The Moore and Glasberg hearing loss simulation model simulates hearing loss by reducing the audibility of the signal, which lowers the thresholds of the listener, and also by smearing the spectral content of the speech, which broadens the auditory filters (Moore & Glasberg, 1993). In Monjot's testing procedure, she used a low-pass frequency filter to reduce the audibility of the signal, however the spectral smearing was not used.

Monjot tested 12 right-handed individuals, 5 male and 7 female, ages 19-23. Her simulated hearing loss model used only the dynamic range portion and did not include spectral smearing to avoid floor effects. Her participants completed six DWR tests, each consisting of 50 dichotic word pairs. The first two tests used a free recall response condition, one in quiet and one with the simulated hearing loss. The next two tests used a directed-attention right response, one in quiet and one with the simulated hearing loss. The last two tests used a directed-attention left response, one in quiet and one with the simulated hearing loss.

Monjot's results showed that the REAs of the young adults were larger in the simulated hearing loss condition but not to a significant degree. She did find significantly larger REAs in the young adults from the directed-attention right when compared to the free recall response and the directed-attention left recall response. The REAs of the young adults with the simulated hearing loss in all response conditions remained significantly smaller than the REAs exhibited by the older adults. Monjot's study concluded that the older adults large REAs are most likely due to auditory processing deficits rather than a sensorineural hearing loss.

## Clinical Implications

Research from the present study can have important clinical implications. The standard practice of audiology currently is to fit elderly individuals with sensorineural hearing loss with binaural hearing aids, a hearing aid for each ear. However, if it can be proven that problems in auditory processing affect the older population in addition to their hearing losses, which is why they exhibit such large REAs, then monaural amplification may be determined as a more appropriate rehabilitation plan (Carter, Noe, & Wilson 2001). Many older adults complain that they can hear the speech stimuli but that they cannot understand what they are hearing. The reason monaural amplification might be more beneficial for these older individuals with clarity problems is because it would allow them to process all incoming information through their right ear, which would travel directly to the left hemisphere. No interhemispheric transfer would have to occur because there would be no incoming information from the left ear traveling to the right hemisphere. This also eliminates the possibility of having distracting information from the left ear interfer with the processing of the information from the right ear.

Present Study

The proposed study will combine Moller's and Monjot's studies to further investigate dichotic word recognition testing and the right ear advantage. Both types of simulated hearing loss, the noise and the Moore and Glasberg model, will be used on each test subject. The introduction of speech spectrum noise to the dichotic listening task will be used in order to reduce overall recognition performance by making the task more difficult for the young adults with normal hearing. After completing the DWR task in noise, the same subject will perform the task again but with the use of the Moore and Glasberg hearing loss simulation model. This model reduces the intensity of the signal to elevate thresholds, and it smears the spectral content of the speech to create broadened auditory filters (Moore & Glasberg 1993).

This proposed study aims to answer the same question posed by both Moller and Monjot: is the large REA exhibited by the elderly listeners due to an age-related sensorineural hearing loss alone or does the aging of the central components of the auditory system play a role? Data collected from this present study will be compared to the Moller (2007), Monjot (2008), and Roup et al. (2006) collected data to answer the following questions:

1. How do the REAs of young adults with normal hearing in the quiet, unprocessed condition compare to the REAs of the same young adults in the noise condition and the Moore and Glasberg simulated hearing loss condition?
2. How does the difference in the mode of hearing loss simulation (noise vs. Moore & Glasberg Model) affect the DWR scores and the REA?

3. How do the REAs of the young adults in both simulated hearing loss conditions compare to the REAs of the older adults with hearing loss?

# Chapter 2

## METHODS

Subjects

Ten individuals ages 21-25 years were recruited from The Ohio State University main campus and surrounding Columbus area to participate in this study. There were six male test subjects and four female test subjects used. All individuals were right-handed because the dichotic testing results of left-handed subjects are less reliable due to their greater variability, and were therefore excluded from this study. Right-handedness was confirmed through the Edinburgh Handedness Inventory (Oldfield, 1971), which is a simple 10-item questionnaire that provides a quantitative assessment of handedness (See Appendix A). Individuals selected for the present study scored $\leq 20$ on the questionnaire to ensure the subjects right-handedness.

The ten selected test subjects also had normal hearing and were required to meet certain inclusion criteria before participation in the present study. All participants had normal otoscopy results with a clear external ear canal, a healthy tympanic membrane, and no signs of structural abnormalities. Tympanometry results were within normal limits, and all individuals were healthy at time of testing with no illness that might have affected hearing performance. Pure tone audiometry was used to assess the individuals hearing. Each test subject had air conduction thresholds of $\leq 20$ dB HL at 250-8000 Hz and bone conduction thresholds were within 10 dB of the air conduction thresholds at 500-4000 Hz indicating no air-bone gap was present. Lastly, all participants were given payment in the amount of $10 per hour to credit them for the time contributed to the study.

Materials

Two-hundred Northwestern University Auditory Test No. 6 (NU-6) monosyllabic words were paired together in order to create 100 dichotic word pairs (see Roup et al., 2006 for details). Two forms of hearing loss simulation were used during the dichotic testing procedure. The first was the presentation of the dichotic word pairs in the presence of background noise. As determined through pilot data gathered by Moller (2007), antiphasic noise was selected as the testing noise type, and the signal-to-noise (SN) ratio was set at +11dB to achieve the most desirable levels of performance.

The other form of simulated hearing loss used was conducted by filtering the word pairs electronically using Moore and Glasberg's (1993) hearing loss simulation model. To create the effect of poorer than normal hearing thresholds, the model reduces the intensity of the signal, and to create the effect of broadened auditory filters, the model smears the spectral content of the speech (Moore & Glasberg, 1993). The thresholds were reduced to a specified amount that was similar to the mean hearing thresholds from the 70-79 year old age group from the Beaver Dam, WI prevalence of hearing loss study (Cruickshanks et al., 1998) and to the mean threshold criteria used from the Roup et al. (2006) study with older adult subjects. This criterion was used to ensure the model simulated the same degree of hearing loss as that of the older adult population. As determined by pilot data conducted by Manjot (2008), this simulation of hearing loss used only the dynamic range reduction portion of the simulation model so as not to result in floor effects.

Procedures

Before the initial testing began, directions were read to the test subjects explaining the dichotic listening task, and all test subjects were familiarized with the dichotic listening procedure by presenting unscored practice word pairs.  The practice set consisted of a 10-item dichotic word set.

Dichotic word recognition testing was measured in three stimulus conditions using a free recall response paradigm for all conditions, and used standardized lists consisting of 50 dichotic word pairs.  Of the three test sections, one was administered under normal listening conditions, one was administered using the noise condition, and one was administered using the Moore and Glasberg Model.  Each stimulus condition was administered using the free recall response paradigm.  When using free recall, the subject was instructed to recall the stimuli from both ears, in any order, and was not instructed to pay attention to any specific ear.

All dichotic word pairs were presented to the listener at 50 dB HL.  After a dichotic word pair was presented, the listener responded verbally and the responses were marked as either correct or incorrect.  No feedback, other than encouragement to continue making the best guesses possible, was provided to the listener. All dichotic word lists were counter-balanced across the 10 subjects to minimize order effects, meaning the order of the listening conditions used during the word pair presentations was changed from subject to subject.

The dichotic stimuli were presented to the listener from a CD player routed to the audiometer and presented to the subject via insert headphones.  The testing was conducted in a double-wall sound booth with the equipment calibrated according to the American National Standards Institute (ANSI, 1987, 2004).  The audiometer's speech signal calibration tone was recalibrated before every new listening condition used.

## Chapter 3

## RESULTS

Comparisons of Adverse Listening Conditions

Statistical results were computed to examine the test findings and are depicted in the following tables and graphs. Table 1 presents mean dichotic word recognition performances (in percent correct) and standard deviations of the right and left ears in the quiet, noise, and simulated hearing loss conditions. Table 1 also shows the right ear advantage in percent, which were computed by subtracting the right ear percent from the left ear percent, for each of the three listening conditions.

The data show that with the introduction of noise and the simulated hearing loss model, overall dichotic word recognition (DWR) scores decreased. The scores for the noise condition were the lowest of the three conditions. Mean performance of the right ear (RE) in quiet was 89%, in noise was 63.2%, and in simulated hearing loss was 78%. Mean performance for the left ear (LE) in quiet was 82.2%, in noise was 52.2%, and in simulated hearing loss was 69.4%. These results can be seen visually in Figure 1, which depicts overall DWR performance in percent correct of the right and left ear for each listening condition.

The right ear advantage (REA) column in Table 1 shows that in all three listening conditions the RE performed better than the LE. These numbers were found by subtracting the LE percentages from the RE percentages for all three listening conditions. REA values in the quiet condition were 6.8%, in the noise condition were 11%, and in the simulated hearing loss condition were 8.6%. These numbers show that the REA increases as the DWR tasks became more difficult.

| | **Right Ear** | **Left Ear** | **REA** |
|---|---|---|---|
| | % | % | % |
| **Quiet Condition** | | | |
| Mean | 89.00 | 82.20 | 6.80 |
| SD | 4.83 | 8.66 | 5.43 |
| **Noise Condition** | | | |
| Mean | 63.20 | 52.20 | 11.00 |
| SD | 6.81 | 8.08 | 7.07 |
| **SimHL Condition** | | | |
| Mean | 78.00 | 69.40 | 8.60 |
| SD | 5.16 | 7.78 | 5.89 |

**Table 1.** Means and standard deviations of DWR performances (in percent correct) for the right ear, left ear, and right ear advantage (right ear – left ear) in the quiet, noise, and simulated hearing loss conditions.

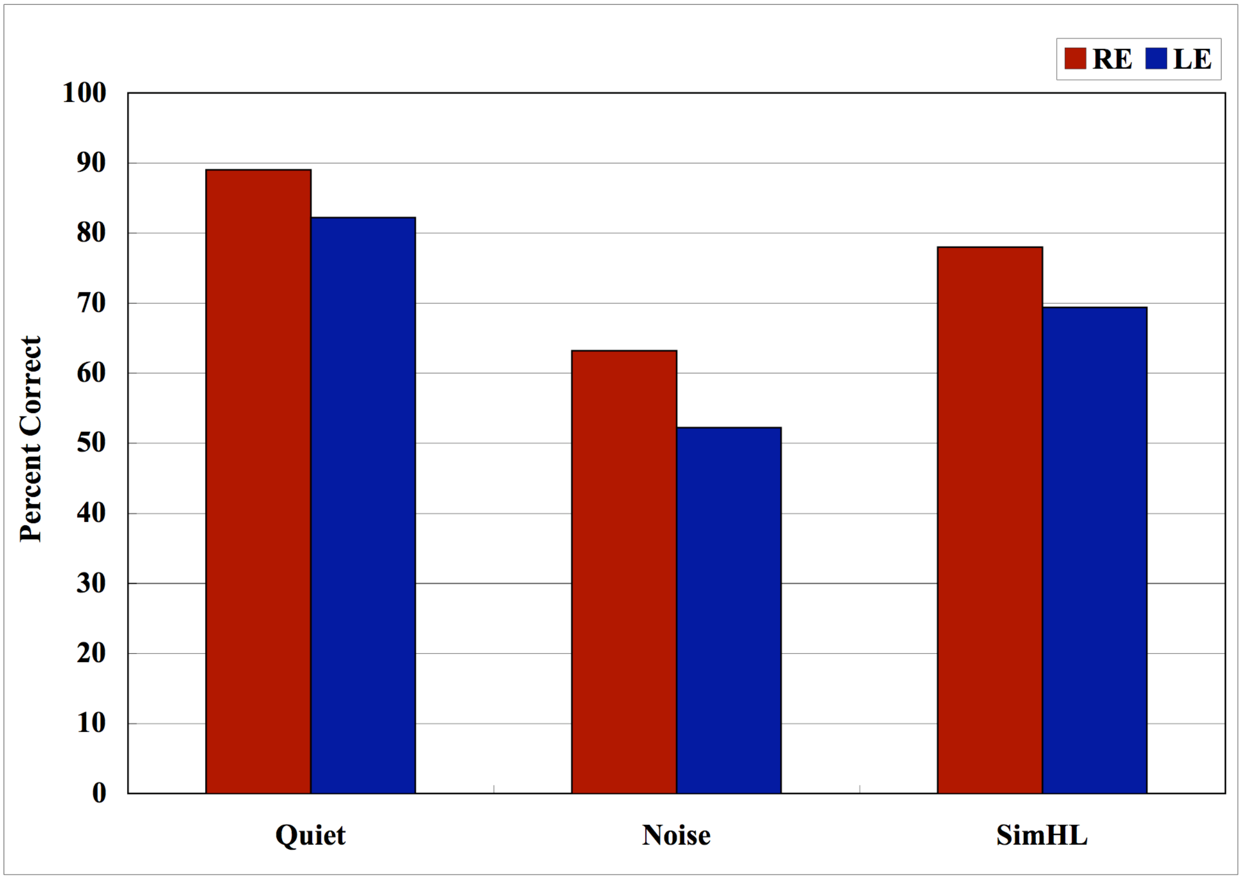


**Figure 1.** Mean dichotic word recognition performance (in percent correct) for the right and left ears of young adults in the quiet, noise, and simulated hearing loss conditions.

Figure 2 illustrates individual dichotic word recognition performance (in percent correct) for each ear in the quiet, noise, and simulated hearing loss conditions. The X-axis represents performance of the RE and the Y-axis represents performance of the LE. Data points that fall below the diagonal line signify a right ear advantage, and points above the line signify a left ear advantage. Figure 2 depicts a decrease in performance and an increase in variability as the conditions change from quiet to simulated hearing loss to noise. The spread of the data values represents variability, with smaller spreads showing less variability and greater spreads showing more variability. The data points are clustered closest together in the quiet condition, are slightly more spread out in the simulated hearing loss condition, and are most loosely clustered in the noise condition. This shows that as the difficulty of the listening task is increased, individual performance becomes much more variable.

Statistical Analysis

In order to eliminate the error associated with percentage data, dichotic word recognition percentage scores were converted to rationalized arcsine units (Studebaker, 1985). To determine if significant differences were present between ears in the different listening conditions, the data were analyzed with a series of *t*-tests of means. Significant differences were observed in overall performance between ears in all listening conditions: in quiet the RE performed significantly better than the LE ($t_9 = 4.6$; $p < .05$), in noise the RE performed significantly better than the LE ($t_9 = 4.9$; $p < .05$), and in simulated hearing loss the RE performed significantly better than the LE ($t_9 = 4.5$; $p < .05$). This indicates that the RE consistently performed better than the LE in all listening conditions during the DWR tasks.

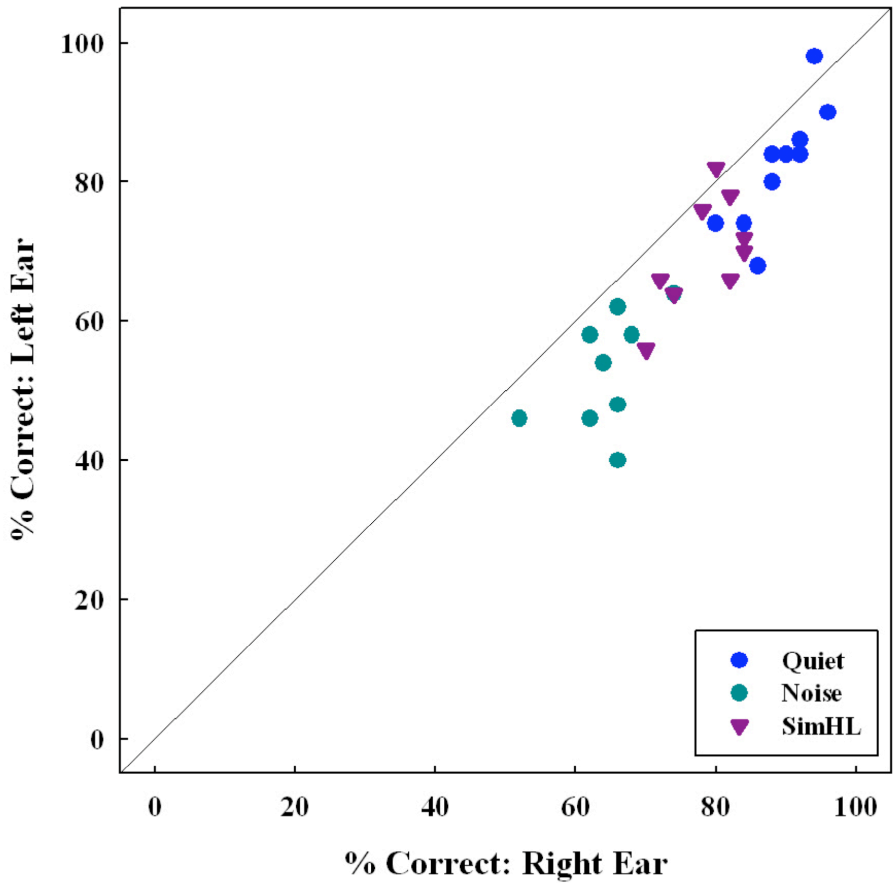


**Figure 2.** Individual data presented as a bivariate plot of percent correct recognition of the right ear and left ear in the quiet, noise, and simulated hearing loss conditions. Data points below the diagonal line represent better performance on words presented to the right ear, whereas data points above the line represent better performance on words presented to the left ear. Data points on the line represent equal performance between the right and left ears.

REAs across the experimental conditions were also analyzed with a series of *t*-tests of means to determine if significant differences were present. The REA of the quiet vs. noise condition was not significantly different ($t_9 = -0.7$; $p > .05$), the REA of the quiet vs. simulated hearing loss condition was not significantly different ($t_9 = -0.1$; $p > .05$), and the REA of the noise vs. simulated hearing loss condition was not significantly different ($t_9 = -0.4$; $p > .05$). These results indicate that while the RE did consistently perform better than the LE in all listening conditions, the size of the REA did not become larger due to the increased difficulty of the listening condition.

Overall performance across the experimental conditions were analyzed with two one-way analysis of variances (ANOVA), one for the RE and one for the LE, to determine if significant differences were present in each ear separately between the three listening conditions. The RE ANOVA showed a significant main effect of conditions. Post-hoc Bonferonni *t*-tests for the RE showed significant differences in performance between quiet vs. noise ($t = 0.000$, $p < 0.017$), between quiet vs. simulated hearing loss ($t = 0.000$, $p < 0.017$), and between noise and simulated hearing loss ($t = 0.000$, $p < 0.017$). The LE ANOVA also showed a significant main effect of conditions. Post-hoc Bonferonni *t*-tests for the LE showed significant differences in performance between quiet vs. noise ($t = 0.000$, $p < 0.017$), between quiet vs. simulated hearing loss ($t = 0.000$, $p < 0.017$), and between noise and simulated hearing loss ($t = 0.000$, $p < 0.017$). These results signify that the addition of noise and simulated hearing loss did significantly reduce subject performance for both ears.

It was expected for performance to be significantly reduced by increasing the difficulty level of the listening task (i.e. introducing noise or simulated hearing loss model), which the results confirmed. It was also expected for the right ear to perform better than the left ear, which the results also show. Given the differences in performance between the right and left ears within each listening condition, and the lack of significant difference in the size of the REAs between the listening conditions, it follows that the REAs were not significantly influenced by the increased difficulty of the listening tasks. Although performance of the RE was significantly better than the LE for all conditions, the REAs were not significantly different between conditions.

Comparisons with Older Adult Data

To allow for direct comparisons of the REAs of young and older adults, the introduction of simulated hearing loss and noise in the DWR tasks of the young adults testing procedure was used to help equate overall performance between the young and older adults. As seen in Figure 3, the REAs of the young adults in the quiet, noise, and simulated hearing loss conditions remained smaller than that of the older adults (Roup et al., 2006) REAs. The differences between the REAs of the young adults and older adults (OA) were the young adults exhibited smaller REAs in all three listening conditions: (1) quiet vs. OA, (2) noise vs. OA, and (3) simulated hearing loss vs. OA.

Figure 4 shows individual performance differences between quiet, noise, simulated hearing loss, and older adults. The older adults performance is much more variable than that of the younger adults in all three listening conditions. There is also a larger amount of data for the older adult population (more subjects were tested), which could contribute to the increased variability. Figure 4 also shows that the majority of the older adult group had poorer DWR performances than the younger adults in all three listening conditions. The addition of noise and simulated hearing loss to the DWR testing of the young adults did not reduce overall performance to a comparable level to that of the older adults.

Comparisons of the REAs of the young and older adults were analyzed with a one-way ANOVA. No significant differences in REA between the young adults conditions and the older adults REAs were shown. This is likely due to the extreme variability exhibited by the older adults (see figure 4).

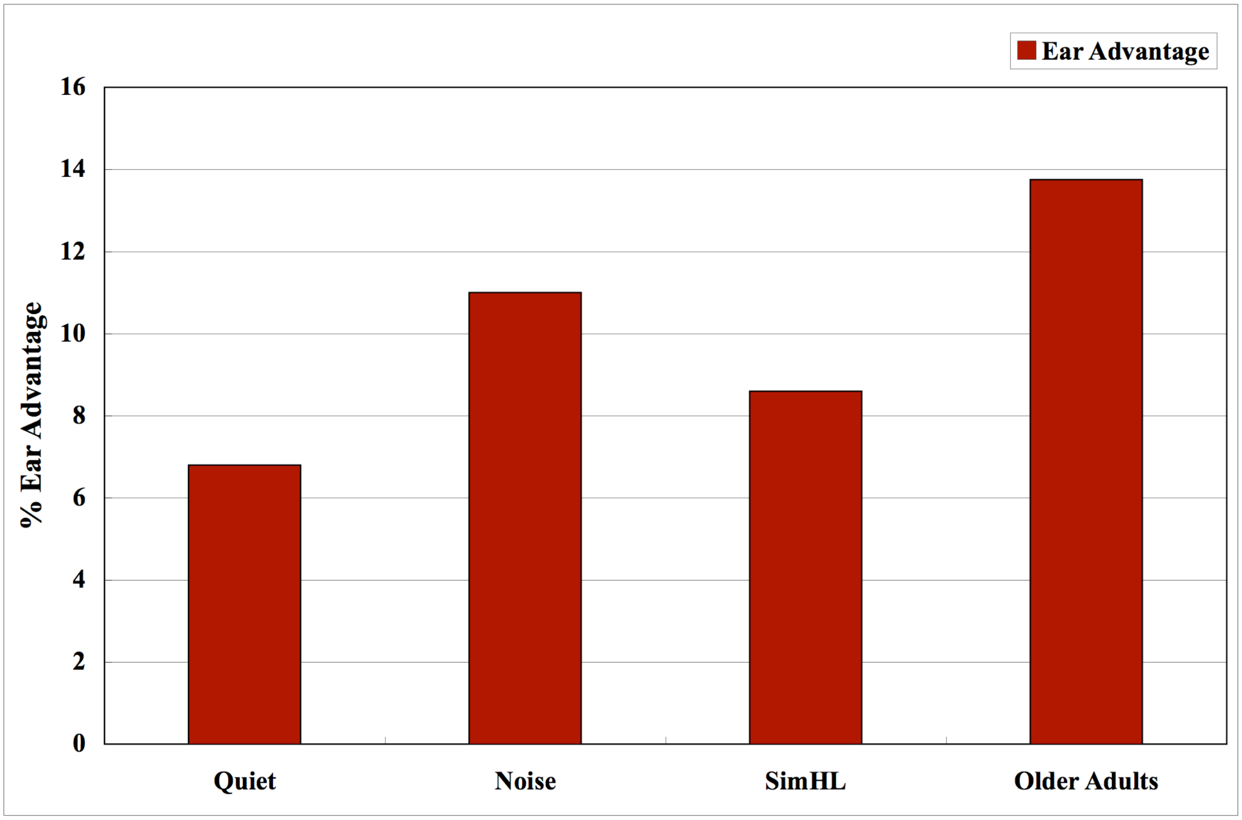


**Figure 3:** Mean REAs (in percent) for the quiet, noise, and simulated hearing loss conditions, and of older adults (Roup et al., 2006).

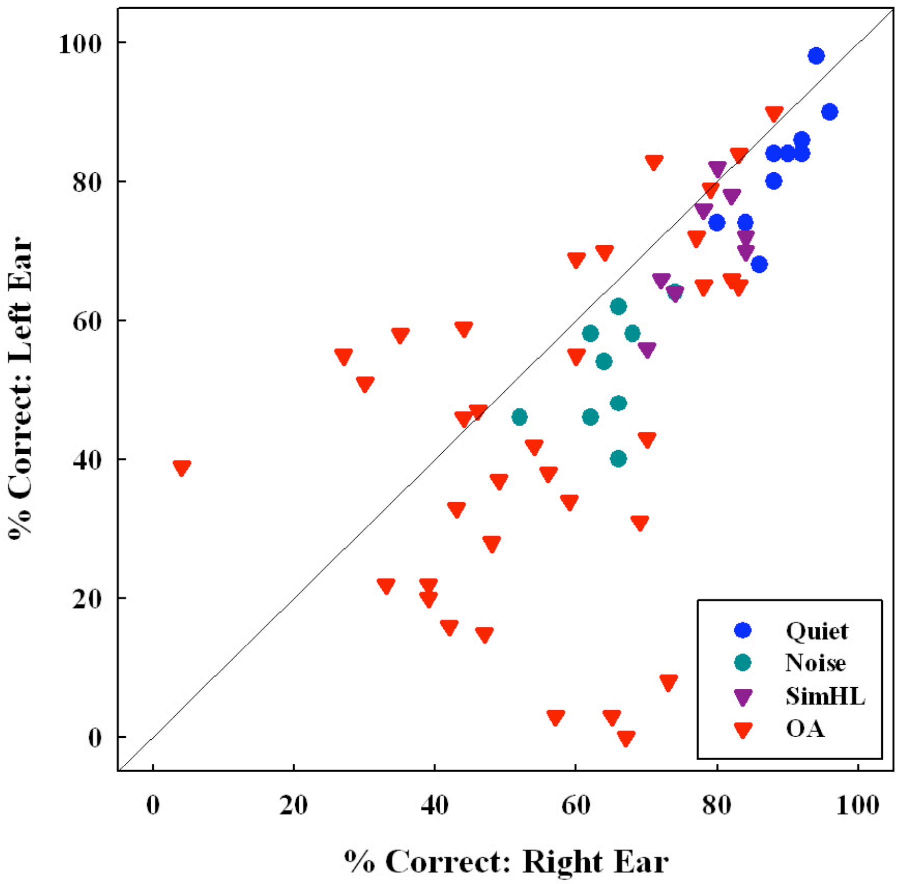


**Figure 4:** Individual data presented as a bivariate plot of percent correct recognition of the right ear and left ear in the quiet, noise, simulated hearing loss conditions, and of older adults (Roup et al., 2006). Data points below the diagonal line represent better performance on words presented to the right ear, whereas data points above the line represent better performance on words presented to the left ear. Data points on the line represent equal performance between the right and left ears.

## Chapter 4

## DISCUSSION

The present study examined dichotic word recognition performance of young adults with normal hearing in adverse listening conditions (quiet, noise, and simulated hearing loss). The purpose was to compare DWR performance of the young adults in each listening condition to that of older adults with sensorineural hearing loss. The results indicated two main findings. First, there were significant decreases in overall DWR performance of the young adults in the noise and simulated hearing loss conditions relative to the quiet condition. The addition of background noise to the listening task resulted in the greatest decrease in performance, and testing in the quiet condition resulted in the best overall performance. The reduced recognition performances in the young adults from the introduction of noise and simulated hearing loss were near equal to that of older adult data reported by Roup et al. (2006). The lack of significant difference in performance between the young adults in noise and the older adult data shows that the reduction of young adult performance was successful. Poorer performance in the simulated hearing loss and noise conditions was unsurprising given the increased difficulty of the tasks. Similar results were reported in previous studies; one by Moller (2007) who examined quiet vs. noise, and the other by Monjot (2008) who examined quiet vs. simulated hearing loss.

Second, despite the decreases in overall recognition performance, the REAs of the young adults were not significantly different across the listening conditions (i.e., they remained relatively small). The young adult REA data was also compared to the older adult data from

Roup et al. (2006). Results revealed that the older adults exhibited a significantly larger REA compared to the young adults, despite the similar levels of overall recognition performance in the noise and simulated hearing loss conditions. This lends support to the proposed hypothesis that the large REAs exhibited by older adults reflect declines in auditory processing rather than their hearing loss. If the large REAs of the older adults were from a hearing loss, then the reduced performances of the young adults in the noise and simulated hearing loss conditions would have resulted in larger REAs that were closer in value to the REAs exhibited by the older adults. However, this was not the case indicating that sensorineural hearing loss is not the cause of the large REAs, but rather a third variable, which is believed to be deficits in auditory processing found in older adults due to aging.

Knowledge of the auditory pathways and interhemispheric transfer can help to better explain the right ear advantage. Auditory stimuli entering the right ear travels contralaterally to the left hemisphere of the brain, where language processing typically occurs. The stimuli entering the left ear travel contralaterally to the right hemisphere where it then must be transferred via the corpus callosum to the left hemisphere for processing. This interhemispheric transfer of the signal from the left ear, which is not necessary for signals presented to the right ear, can result in the right ear advantage during dichotic listening tasks. Deficits in interhemispheric transfer, or auditory processing, occur as people age making it more difficult for the signal from the left ear to reach the language-processing center.

Research has shown that older adults perform more poorly on dichotic recognition tasks and show larger REAs when compared to younger adults (Bellis & Wilber, 2000; Roup et al., 2006; Strouse & Wilson, 1999). Poorer overall recognition performance is expected from the older adults due to presbycusis, the natural aging of the hearing mechanism that results in sensorineural hearing loss. The larger REAs, however, are not as easily explained. Researchers have suggested the large REAs exhibited by the older adults may be due in part to an additional loss of energy during the interhemispheric transfer that occurs with the aging of the central auditory pathways (Jerger, Alford, Lew, Rivera, & Chmiel, 1995). Results from the present study when compared to the older adult data from Roup et al. (2006) support Jerger and his colleagues theory: differences in REAs between young adults with normal hearing and older adults with sensorineural hearing loss may be due to central auditory processing deficits, in addition to the hearing loss in the older adults caused by aging.

## Clinical Implications and Future Research

The results of the present study suggest that the older adults have an auditory processing deficit in addition to a hearing loss, because the young adults' REAs remained small and insignificant despite the reduction in performance from the adverse listening conditions, while the older adults REAs were significantly larger. Dichotic word recognition testing has the potential to aid in the diagnosis of auditory processing deficits, which in turn may result in more successful hearing aid fittings for older adults. The standard practice of audiology currently is to fit elderly individuals with sensorineural hearing loss with binaural hearing aids. However, if it can be proven that problems in auditory processing affect the older population and their hearing losses, which is why they exhibit such large REAs, then monaural amplification may be determined as a more appropriate rehabilitation plan (Carter, Noe, & Wilson 2001). Declines in auditory processing among older adults have been associated with difficulty in the use of bilateral hearing aids. The reason monaural amplification might be more beneficial for those older individuals is because it would allow them to process all incoming information through their right ear, which would travel contralaterally to the left hemisphere for immediate language processing and no interhemispheric transfer would have to occur. This also eliminates the possibility of having distracting information from the left ear interfering with the processing of the information from the right ear.

Future research should be conducted to further substantiate the results of this study. A greater number of test subjects should be used in future research because of the large variability encountered with using only ten subjects. Another change to be made is improving the hearing loss simulation model. The difficulty of this listening condition should be increased; however, this has not yet been developed. If young adult performances in the simulated hearing loss condition can be more closely reduced to the older adult performances, comparisons between the two groups would be more beneficial than with the noise condition because of the greater similarity to a sensorineural hearing loss. Future research could also compare older adults with hearing loss to older adults without hearing loss. Investigating ear advantages of older adults without hearing loss would be very informative. If this population exhibits significant REAs without the age-related hearing loss, it would indicate an age-related deficit in auditory processing, strengthening the hypothesis that the large REAs are not from a hearing loss.

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**APPENDIX A**

Handedness Inventory

*Please indicate your preferences in the use of hands in the following activities by checking the appropriate column.*

*Some of the activities require both hands. In these cases the part of the tas, or object, for which hand preference is wanted is indicated in brackets.*

*Please try to answer all the questions, and only leave a blank if you have no experience at all of the object or task.*

Place ++ in the right column if you always use the right hand. Place a + in the right column if you mostly use the right hand. Place a + in both columns if you feel indifferent. Place a ++ in the left column if you always use the left hand. Place a + in the left column if you mostly use the left hand.

A ++ in the right column gets 1 point, a + in the right column gets 2 points, a + in both columns gets 3 points, a + in the left column gets 4 points, a ++ in the left column gets 5 points. Add up the total amount of points. To be considered right hand dominate the total number of points must be $\leq 20$.

| | LEFT | RIGHT |
|---|---|---|
| 1. Writing | | |
| 2. Drawing | | |
| 3. Throwing | | |
| 4. Scissors | | |
| 5. Toothbrush | | |
| 6. Knife (without fork) | | |
| 7. Spoon | | |
| 8. Broom (upper hand) | | |

| | | |
|---|---|---|
| 9. Striking match | | |
| 10. Opening box (lid) | | |